PATENT SPECIFICATION

NO DRAWINGS

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COMPLETE SPECIFICATION

Improvements relating to the Suppression of Noise from Electromagnetic Apparatus

We, ASSOCIATED ELECTRICAL INDUSTRIES LIMITED, a British Company having its registered office at 33 Grosvenor Place, London, S.W.1, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to the suppression of noise from liquid-cooled electromagnetic apparatus (e.g. electrical transformers) of the kind operated with alternating or periodically varying flux and accommodated within a tank containing the liquid coolant.

In the case of electrical transformers operating at 50 cycles per second, the noise emitted by the transformer consists of a harmonic series of components having a fundamental frequency of 100 cycles per second.

As is well known, this fundamental frequency results from the main 50-cycle magnetising flux since the un-polarised iron of the magnetic circuit vibrates at twice the supply frequency. The harmonics in the noise can be caused by harmonics in the voltage and flux waves but even with sinusoidal voltage and flux waveforms, harmonics can be produced by a number of causes, for example non-linearity in the magneto-striction effect and the effect of core joints, accentuated in some cases by mechanical resonance in some parts of the transformer structure.

In accordance with our Patent No. 726,910 provision may be made for adjusting the harmonic content of the magnetising force of a transformer so as to nullify or attenuate substantially all of the noise-producing harmonics and leaving a pure or substantially pure fundamental frequency component of 100 cycles per second in the case of a transformer operating from a 50 cycles per second supply. With small transformers the amplitude of this fundamental component frequency of which the human ear is comparatively insensitive at low intensities is such that it produces negligible loudness sensation in comparison with the harmonics but with large power transformers having large fundamental components the noise emitted may tend to reach an objectionable level.

According to another arrangement for reducing the volume of noise emitted from electrical transformers loudspeakers located in the vicinity of the transformer are energised so as to produce air-borne vibrations of suitable frequencies tending to nullify the various noise-producing components emanating from the transformer. It has been found however that the efficacy of this arrangement tends to be effected by changes in climatic conditions and moreover it is usually only possible to obtain a moderate reduction in noise over a limited area with the risk of increased noise in adjacent areas.

According to the present invention electromagnetic apparatus (e.g. an electrical transformer) of the kind referred to has in combination therewith means for producing in the coolant for the apparatus vibrations having the same frequency but in phase opposition to at least one of the noise producing components transmitted to the coolant by said apparatus, whereby the said component will be nullified or at least attenuated.

By means of the present invention the fundamental component emitted by the transformer or other apparatus as well as several of the noise-producing harmonics may be completely eliminated or substantially attenuated by producing appropriate vibrations in the coolant.

The reduction in noise emission in accordance with the invention is moreover substantially independent of changes in climatic con-

ditions by virtue of the fact that the noise producing components are nullified or attenuated before becoming airborne. Furthermore less critical adjustments need be made to the phases of the vibrations produced in the coolant since the wavelengths of said vibrations in the coolant are large compared with the wavelengths of corresponding vibrations in air. Still further, the invention does not require any modification of the apparatus *per se* or of its mode of operation so that the invention can readily be applied to conventionally manufactured apparatus.

The means for producing the noise suppressing vibrations in the coolant preferably takes the form of one or more moving coil vibrator units arranged with their moving elements connected to the coolant tank walls so that the latter and the coolant within the tank will be set in vibration responsively to the variable energisation of the windings of the vibrator unit or units. The vibrator unit or units may conveniently be mounted on a rigid support frame for the tank and the number of units employed will be determined in accordance with the size of the apparatus, a plurality of units per tank wall being contemplated in the case of large power transformers.

Alternatively the moving coil vibrator unit(s) referred to above instead of being coupled with the tank walls for vibration thereof may have diaphragms in direct contact with the coolant or still further moving iron vibrator unit(s) may alternatively be employed and arranged with their vibrating diaphragms in contact with the coolant.

In yet another arrangement, suitable for nullifying or attenuating the lower frequency noise producing components (e.g. the 100 cycles per second fundamental component in the case of a 50 cycle transformer) the tank walls are set in vibration by means of a dynamically unbalanced rotating shaft supported by bearings mounted on the tank and driven by means of an electric motor synchronised to the main supply of the apparatus. Phase adjustment of the vibrations so produced in the tank and coolant may be effected either by varying the phase of the motor supply or by angular adjustment of a mass producing unbalance of the shaft, the magnitude of the vibrations being varied as desired by adjusting the mass or its radial distance from the shaft axis.

With noise suppressing arrangements according to the invention using moving coil vibrator unit(s) the windings of the unit(s) may be energised from a number of small alternators producing respective outputs having frequencies corresponding to the noise-producing components it is desired to suppress. These alternators may have their rotors mounted on a common shaft and have numbers of poles such as to provide the required harmonic frequencies, the common shaft being driven by a synchronous motor connected with the main supply to the apparatus so as to be rotated at a speed proportional to the fundamental frequency of said supply. Means such as worm gearing are provided for adjusting the relative angular positions of the stators relative to the rotors so that the phase relation of each alternator output with respect to the main supply can be adjusted. Variable resistors or other means are provided for adjusting the amplitude of the several outputs and correction circuits may be employed to ensure sinusoidal outputs from the alternators. The alternators may be of rotating magnet, induction or other type. Where induction type alternators are employed they will be run at half synchronous speed.

Alternatively the components it is desired to suppress are recorded magnetically on a recorder of the tape or disk type and reproduced and amplified before being fed to the windings of the vibrator unit(s). Separate recording tracks and reproducing heads may be employed for the several components respectively; the reproducing heads for each of the component frequencies are then mounted for individual adjustment in position in the direction of movement of the tape or disk to provide phase adjustment. The tape or disk may be driven by a gramophone type of motor. The output from the reproducing heads will be applied to the input of an electronic or other amplifier, the output of which is connected with the windings of the vibrator unit(s).

In a further arrangement for supplying the vibrator unit(s) a magnetically saturated transformer is arranged to supply the odd harmonics, and/or a rectifier arrangement connected with the 50 cycle or other fundamental frequency supply is arranged to supply the even harmonics, *per se* in accordance with well-known techniques. Inductive or capacitive phase shifting circuits are provided for adjusting the phase relations and if necessary the circuits generating each of the harmonics may include a resonant circuit tuned to the required frequency. In a still further arrangement, currents for energising the unit(s) are generated by an electronic generator which may, for example, comprise a number of separate oscillators operating respectively at the required component frequencies, or may comprise a square wave generator with filter and phase shift circuits for each of the required component frequencies.

Whatever arrangement is employed for supplying the vibrator unit(s) the power consumed by the latter for the suppression of the noise-producing components will be small compared with rating of the apparatus.

It is also contemplated providing a feed back arrangement which serves for automatically adjusting the magnitudes of the noise-suppressing vibrations so as to provide maximum noise suppression and in which elec-

tric signals derived from vibrations in the coolant are utilised for producing further vibrations in the coolant tending to nullify the vibrations which produced the aforesaid electric signals.

Furthermore, to avoid the direct transmission of the noise-producing components to the tank the apparatus may be resiliently mounted within the latter.

WHAT WE CLAIM IS:—

1. Electromagnetic apparatus of the kind hereinbefore referred to comprising means for producing in the coolant for said apparatus vibrations having the same frequency but in phase opposition to at least one of the noise producing components transmitted to the coolant by said apparatus, whereby the said component will be nullified or at least attenuated.

2. Electromagnetic apparatus as claimed in Claim 1, in which the means for producing the noise suppressing vibrations in the coolant takes the form of one or more moving coil vibrator units arranged with their moving element(s) connected to the tank so that the latter and the coolant within the said tank will be set in vibration responsive to the variable energisation of the coil(s) of the vibrator unit or units.

3. Electromagnetic apparatus as claimed in Claim 2, in which the vibrator unit or units are mounted on a rigid support frame for the tank.

4. Electromagnetic apparatus as claimed in Claim 1, in which the means for producing the noise suppressing vibrations in the coolant comprises one or more moving coil vibrator units having vibrating diaphragms arranged in direct contact with the coolant.

5. Electromagnetic apparatus as claimed in Claim 1, in which the means for producing the noise suppressing vibrations in the coolant comprises one or more moving iron vibrator units, having vibrating diaphragms in contact with the coolant.

6. Electromagnetic apparatus as claimed in Claim 1, in which the tank is set in vibration for producing the noise suppressing vibrations in the coolant by means of a dynamically unbalanced rotating shaft supported by bearings mounted on the tank and driven by means of an electric motor synchronised to the main supply of the apparatus.

7. Electromagnetic apparatus as claimed in Claim 6, in which phase adjustment of the vibrations produced in the coolant is effected either by varying the phase of the motor supply or by adjustment of the angular position of a mass producing unbalance of the shaft, the magnitude of the vibrations in the latter case being adjusted by varying the mass or its radial distance from the shaft axis.

8. Electromagnetic apparatus as claimed in any of Claims 2 to 4, in which the coils of the moving coil vibrator units are energised from a number of small alternators producing respective outputs with frequencies corresponding to the components it is desired to suppress.

9. Electromagnetic apparatus as claimed in Claim 8, in which the alternators have their rotors mounted on a common shaft and have numbers of poles such as to provide the required harmonic frequencies, the common shaft being driven by a synchronised motor connected with the main supply to the apparatus so as to be rotated at a speed proportional to the fundamental frequency of said supply.

10. Electromagnetic apparatus as claimed in Claim 9, in which adjustment of the angular positions of the stators relative to the rotors is provided by worm gearing so that the phase relation of each alternator output with respect to the main supply can be adjusted.

11. Electromagnetic apparatus as claimed in Claim 8 or 9, in which the alternators are of the rotating magnet or induction type.

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PROVISIONAL SPECIFICATION

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Whatever arrangement is employed for supplying the vibrator unit(s) the power consumed by the latter for the suppression of the noise-producing components will be small compared with rating of the apparatus. It is also contemplated providing a feed back arrangement which serves for automatically adjusting the magnitudes of the noise-suppressing vibrations so as to provide maximum noise suppression.

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